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Requirements Engineering Model in Designing Complex Systems

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Abstract: This research tends to development of the requirements elicitation methodology with regard to operational nature and hierarchical analysis for complex systems and also, regarding available technologies. This methodology applies Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) to ensure traceability of planned qualitative and quantitative data from requirements to available technologies in hierarchical model. Studies show that about 22% of project failures in complex systems relate to incomplete requirements and variation in requirements. This methodology tends to increase knowledge and decrease uncertainties through leading design team in a structured process. Based on previous methods, a new methodology developed to remove the above-said complexity or challenges, performing to hierarchically decrease requirements i.e expectations of the stakeholders, i.e accessible technologies in developing system. A category of requirements is created to classify the information gathered during the problem definition. This research applies to aerial systems as systems with high complexity for methodology validation.

Keywords: Requirements Elicitation, Available Technologies, Hierarchical Analysis, Decision Making.

1. Introduction

Generally, design process divides into three phases including: conceptual, preliminary and detail design, as shown in figure 1. In this figure, design process starts with a group of preliminary requirements and it completes upon construction of systems using available technologies. All activities effectively influence on stability and quality of final product through the process. Requirements play role of a bridge (data connection) which is transferred to accessible technologies and vs. amongst costumers. Basic objective of requirements deals with reaching costumers' needs in a way of leading to a best configuration or compromise configurations of the available technologies. Requirements are basis of the present research. International Council on Systems Engineering (INCOSE) defines the following requirements (U.S. General Accounting Office, 2001).

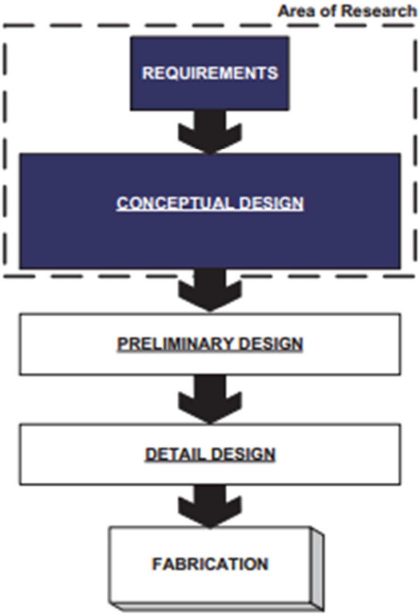


Figure 1. Traditional Design Process

"Requirement: a statement that identifies features and limits of a system, product or process while being explicit and measurable and is necessary for satisfy clients or stakeholders". Requirements should have been mapped to the stakeholders, systems and also available technologies. Relations of requirements and stakeholders show system's level of success. It is to be noted that relations of requirements and systems deal with influences of requirements on systems and then, on activation of testing process and validation of requirements. Requirements should be more explicit to perform testing process. Each industrial process has limitations in time, technology, knowledge and financial resources (Jordan, *et al.*, 2006) Subsequently, strategies are created to allocate resources for ensuring project success. It is difficult to allocate resources in a complex system with a range of requirements, because this results in lack of satisfaction of some requirements leading in lack of satisfaction of some stakeholders (U.S. General Accounting Office, 2001). This results in requirements selection (or analysis) process. Analyzing importance of requirements in project success implies on relation of project success and evaluation of requirements influences on system. Report of General Accounting Office (GAO) believes that project success key deals with interrelation of project requirements and available technologies (INCOSE, 2006). To reach this objective, it suggests that there should be an interaction between project design and stakeholders expectations. This factor results in showing requirements process as shown in figure 2. This figure shows a route held in requirements for coordination of resources along with expectations.

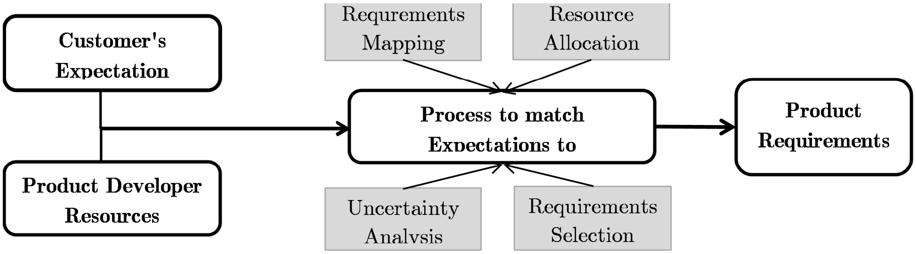


Figure 2. Requirements Process (GAO)

Importance of interrelating clients' expectations and available technologies relates with costs of project formation in conceptual design. Loucopoulos emphasized that (requirements engineering) is a key activity in system development because if there is any fault in determination of preliminary requirements, most cost of repairs (maintenance) deal with implementation of system (Loucopoulos and Karakostas, 1995).

2. Literature Review

This section presents an overview on methods and studies performed in requirements analysis, while showing weaknesses of applied methods. There are differences in Quality Function Development (QFD) methods while having similar logic and reasoning and most of them start from a matrix named “House of Quality (HoQ)”. In this part, focus of discussion is on first matrix or HoQ which shows its completion process with a consumptive example. Figure 3 shows different parts of HoQ matrix.

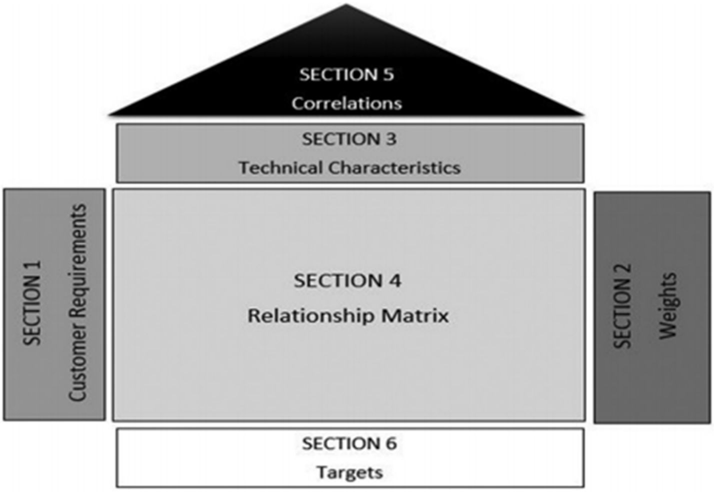


Figure 3. Different Parts of House of Quality matrix

Most experts and members of executive team of QFD faces the following question upon completion of completion of House of Quality: “What are extractable contents of House of Quality?” General contents of House of Quality are:

- Determining most important technical feature of product (based on absolute weight)
- Determining strengths of quality requirements in comparison with products of other competitors (analyzing competitors evaluation results in right hand of matrix)

- Determining strengths of product technical features' requirements in comparison with products of other competitors (analyzing competitors evaluation results in downside of matrix)
- Determining correlation value of technical features of products
- Identifying and reviewing optimization chances (patterning results in right hand of matrix)

Table 1 shows a number of performed studies in different fields of requirements analysis, performed using QFD.

Table 1. A Review on QFD

Research Area	Resources	Publication Year	Research Objectives
Definition of Requirements	5	2000	Evaluating more than 400 companies in USA and Japan in application of QFD
	6	2000	Applying QFD process for processing client requirements
	7	2004	Combining Kanu Model with QFD for meeting client requirements
Product Design	8	1998	Selecting optimized combination of engineering features in combination of QFD with MADM methods
	9	2002	Optimizing quality using combination of QFD with FEMA, DFA & AHP
Decision Model for Allocating Resources	10	1996	Completing HoQ matrix using learning neural networks
	11	2000	Discussing on application of fuzzy logic, neural networks and Taguchi method
	12	2002	Optimizing client satisfaction using variations in engineering features
	13	1998	Reviewing product resources in QFD process
	14	1998	Allocating resources to engineering features to maximally satisfy clients
	15	2002	
	16	2003	

Firstly, this section explains failure causes of designing projects in figure 2. As figure 2 shows, 22% of projects' failures directly deal with requirements, variable and incomplete requirements. Main causes in relation with requirements groups include: weak configuration, lack of explicit expression, weak relations with others, very quick changes, unrealistic and unnecessary expectations (Hull, *et al.*, 2002). Most of the mentioned causes are subgroups for incomplete requirements, stakeholders and systems.

Table 2. Causes for Projects' Failures

Reasons	Failure Probability (in %)
Incomplete Requirements	13.1
Lack of engaged users	12.4
Lack of resources	10.6
Unrealistic expectations	9.9
Lack of executive supports	9.3
Requirements Variations	8.7
Incomplete Programming	8.1
No need to develop product	7.5

3. Method

This section tends to formulate suggested methodology using relations of requirements analysis steps along with investigated approaches. Requirement classification enters firstly in time of problem definition. Requirements classification objective deals with arrangement of information obtained from stakeholders, previous data and scientific databases taken from previous designing projects. First challenge deals with creation and organization of classes. Classes are required to be applicable in different fields and also, specialized enough to cover all types of requirements.

4. Findings

In completion and arrangement of problem identification information gained from step 1, objective of step 2 is creation of a configured map which ensures relation of stakeholders' expectations and available technologies. Figure 5 in schematic and brief for shows performance of functions and operational features in expectations of stakeholders up to operations and systems for designing in aerospace area. Mapping with stakeholders' expectations starts in form of "subject, verb and object." With these expectations, next activity deals with identification of systems and tasks. Operational tasks are taken from operational content (CONOPS) while systems are taken of systems architecture (like aircraft body, propulsion, power, etc.). INCOSE defines CONOPS as: "operating system as per operator desires". Based on CONOPS and systems, designing team is able to provide a list of features (efficiency rate) to realize expectations (like weight, power, modularity, etc.). Subsequently, the last step deals with collection of these elements for expression of requirements statement which include capability (expectation or function), feature (MoP or MOE) and also (physical or operational) limits, if required.

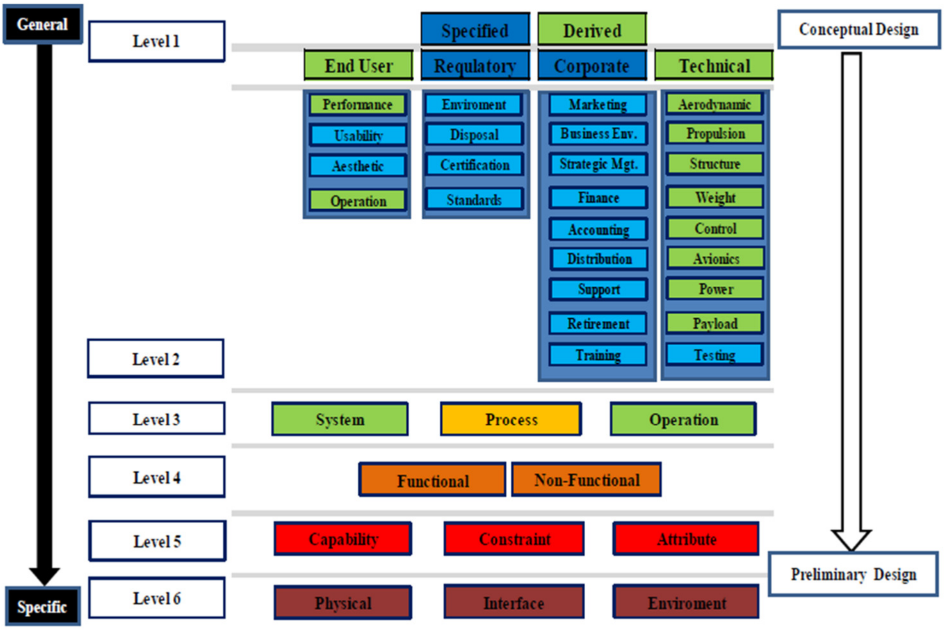


Figure 4. Classification of Requirements in Aerial Systems

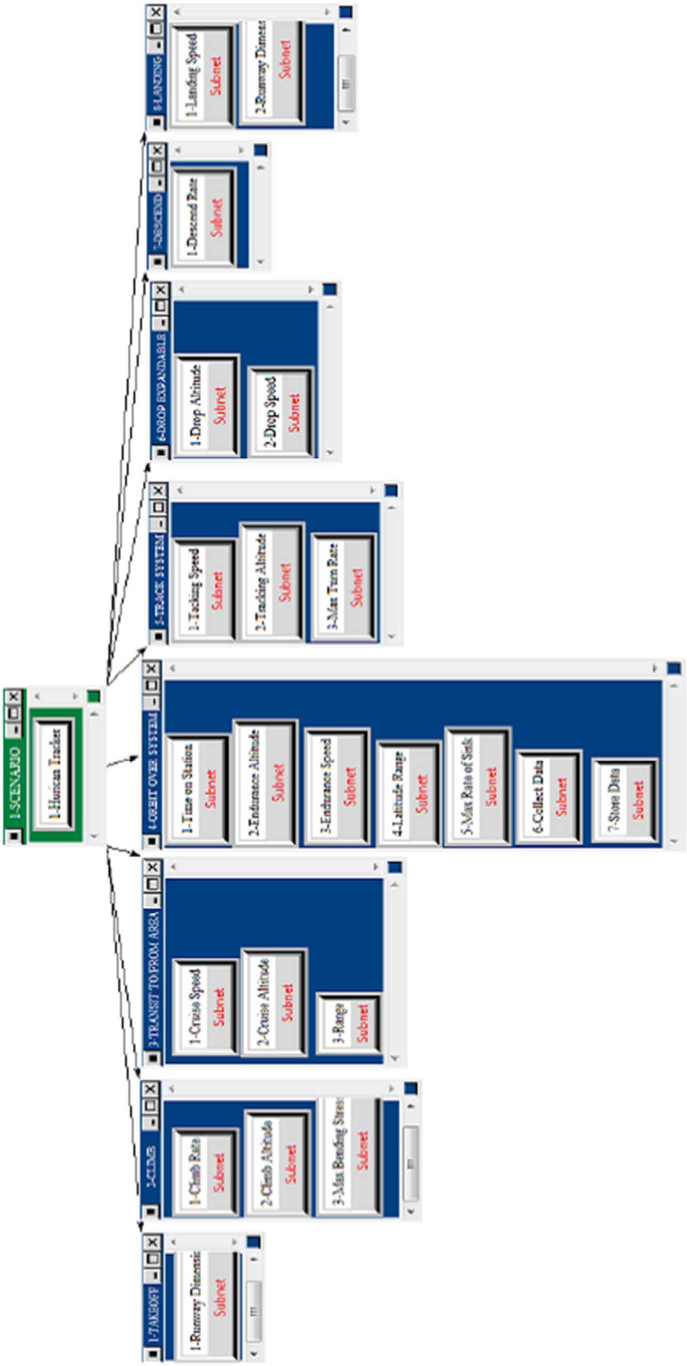
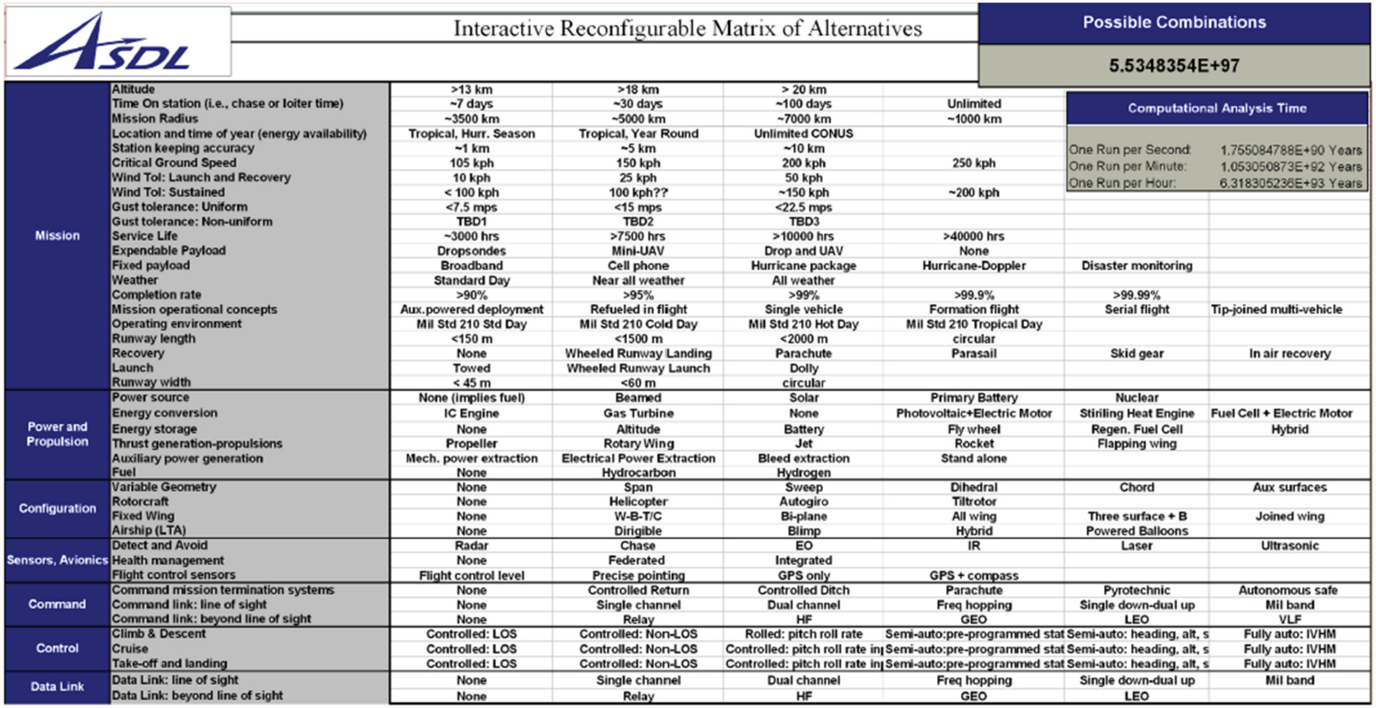


Figure 5. Samples of Hierarchical Structure for a Bird in Super Decisions

One example of operational function is “circulation of aircraft around considered area”. For this function “objective time” and “maximal height” are examples of functional features (OPS.MOE). For propulsion system, one functional example is “conversion of energy to mechanical power” using “Trust Motor” and “energy consumption” as features of propulsion system (Sys.MOE). Key activity is combination of these systems and mission segments and efficiency rate (MoEs) and mapping to network (ANP) or hierarchy (AHP). As mapping develops from operation to system (move top-down); concentration changes from “type of target” to “how to reach target”. Systems are defined through their MoEs depending on available technologies for each Sys.MoE. This research investigates levels of hierarchical model of decision for a complex system in aerial industries, as follows: first step: Mission Segments Model, second step: OPS.MoEs, third step: systems and fourth step: Sys.MoEs

After clarifying mapping of systems and performances, available technologies will be determined using morphological analysis content. This research tends to classify a system to a number of sub-systems and identification of potential technologies per sub-systems. Figure 6 shows a matrix of available technologies taken from resource (McClure, 2006) for an aerial bird.

Whereas combination of available technologies for systems bear incompatibilities, it possibly applies two technologies in developing system which is practically impossible; all incompatibilities should be omitted after creating available technologies’ matrices. Figure 7 shows a sample of available technologies for propulsion system, fuel and birth power.



Interactive Reconfigurable Matrix of Alternatives

Possible Combinations

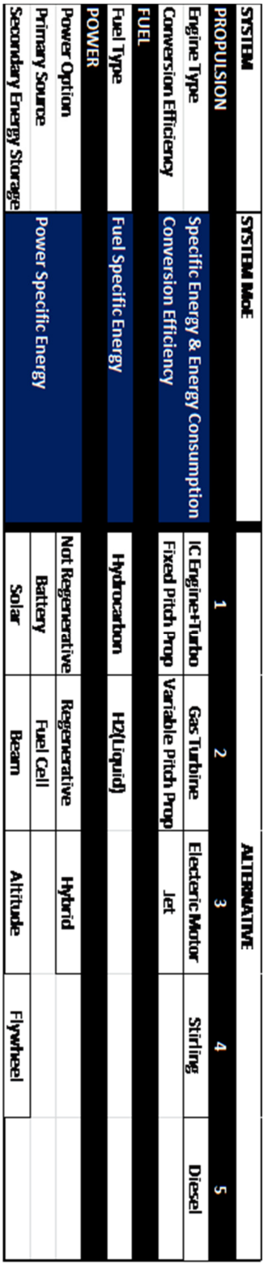
5.5348354E+97

Computational Analysis Time

One Run per Second: 1.755084788E+90 Years
One Run per Minute: 1.053050873E+92 Years
One Run per Hour: 6.318305236E+93 Years

Mission	Altitude	>13 km	>18 km	> 20 km			
	Time On station (i.e., chase or loiter time)	~7 days	~30 days	~100 days	Unlimited		
	Mission Radius	~3500 km	~5000 km	~7000 km	~1000 km		
	Location and time of year (energy availability)	Tropical, Hurr. Season	Tropical, Year Round	Unlimited CONUS			
	Station keeping accuracy	~1 km	~5 km	~10 km			
	Critical Ground Speed	105 kph	150 kph	200 kph	250 kph		
	Wind Tol: Launch and Recovery	10 kph	25 kph	50 kph			
	Wind Tol: Sustained	< 100 kph	100 kph??	~150 kph	~200 kph		
	Gust tolerance: Uniform	<7.5 mps	<15 mps	<22.5 mps			
	Gust tolerance: Non-uniform	TBD1	TBD2	TBD3			
	Service Life	~3000 hrs	>7500 hrs	>10000 hrs	>40000 hrs		
	Expendable Payload	Dropsondes	Mini-UAV	Drop and UAV	None		
	Fixed payload	Broadband	Cell phone	Hurricane package	Hurricane-Doppler	Disaster monitoring	
	Weather	Standard Day	Near all weather	All weather			
	Completion rate	>90%	>95%	>99%	>99.9%	>99.99%	
	Mission operational concepts	Aux.powered deployment	Refueled in flight	Single vehicle	Formation flight	Serial flight	Tip-joined multi-vehicle
	Operating environment	Mil Std 210 Std Day	Mil Std 210 Cold Day	Mil Std 210 Hot Day	Mil Std 210 Tropical Day		
	Runway length	<150 m	<1500 m	<2000 m	circular		
	Recovery	None	Wheeled Runway Landing	Parachute	Parasail	Skid gear	In air recovery
	Launch	Towed	Wheeled Runway Launch	Dolly			
	Runway width	< 45 m	<60 m	circular			
Power and Propulsion	Power source	None (implies fuel)	Beamed	Solar	Primary Battery	Nuclear	
	Energy conversion	IC Engine	Gas Turbine	None	Photovoltaic+Electric Motor	Stiriling Heat Engine	Fuel Cell + Electric Motor
	Energy storage	None	Altitude	Battery	Fly wheel	Regen. Fuel Cell	Hybrid
	Thrust generation-propulsions	Propeller	Rotary Wing	Jet	Rocket	Flapping wing	
	Auxiliary power generation	Mech. power extraction	Electrical Power Extraction	Bleed extraction	Stand alone		
	Fuel	None	Hydrocarbon	Hydrogen			
Configuration	Variable Geometry	None	Span	Sweep	Dihedral	Chord	Aux surfaces
	Rotorcraft	None	Helicopter	Autogiro	Tiltrotor		
	Fixed Wing	None	W-B-T/C	Bi-plane	All wing	Three surface + B	Joined wing
	Airship (LTA)	None	Dirigible	Blimp	Hybrid	Powered Balloons	
Sensors, Avionics	Detect and Avoid	Radar	Chase	EO	IR	Laser	Ultrasonic
	Health management	None	Federated	Integrated			
	Flight control sensors	Flight control level	Precise pointing	GPS only	GPS + compass		
Command	Command mission termination systems	None	Controlled Return	Controlled Ditch	Parachute	Pyrotechnic	Autonomous safe
	Command link: line of sight	None	Single channel	Dual channel	Freq hopping	Single down-dual up	Mil band
	Command link: beyond line of sight	None	Relay	HF	GEO	LEO	VLF
Control	Climb & Descent	Controlled: LOS	Controlled: Non-LOS	Rolled: pitch roll rate	Semi-auto:pre-programmed stat	Semi-auto: heading, alt, s	Fully auto: IVHM
	Cruise	Controlled: LOS	Controlled: Non-LOS	Controlled: pitch roll rate in	Semi-auto:pre-programmed stat	Semi-auto: heading, alt, s	Fully auto: IVHM
	Take-off and landing	Controlled: LOS	Controlled: Non-LOS	Controlled: pitch roll rate in	Semi-auto:pre-programmed stat	Semi-auto: heading, alt, s	Fully auto: IVHM
Data Link	Data Link: line of sight	None	Single channel	Dual channel	Freq hopping	Single down-dual up	Mil band
	Data Link: beyond line of sight	None	Relay	HF	GEO	LEO	

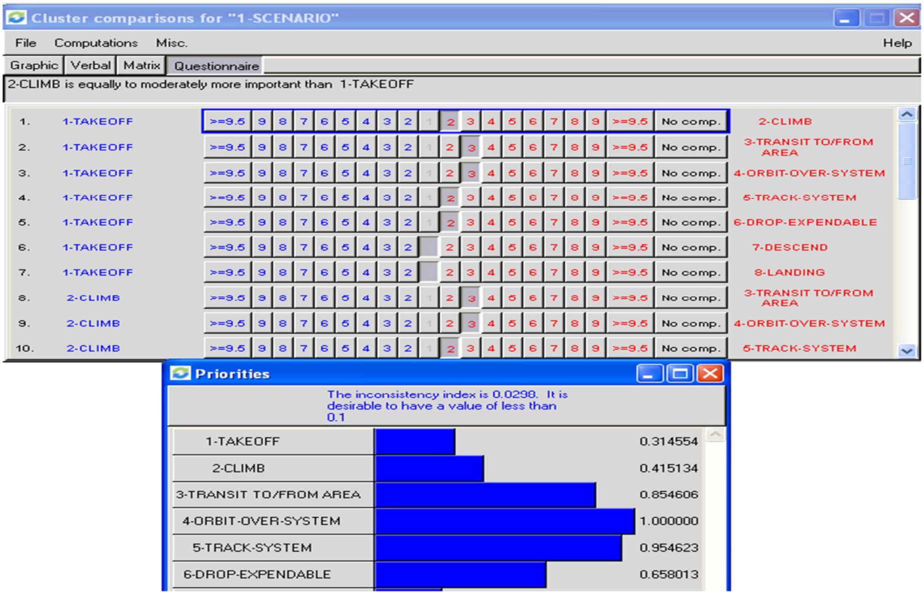
Figure 6. Morphological Matrix



SYSTEM	SYSTEM MoE	ALTERNATIVE				
PROPULSION		1	2	3	4	5
Engine Type	Specific Energy & Energy Consumption	IC Engine+Turbo	Gas Turbine	Electeric Motor	Stirling	Diesel
Conversion Efficiency	Conversion Efficiency	Fixed Pitch Prop	Variable Pitch Prop	Jet		
FUEL						
Fuel Type	Fuel Specific Energy	Hydrocarbon	H2(Liquid)			
POWER						
Power Option	Power Specific Energy	Not Regenerative	Regenerative	Hybrid		
Primary Source		Battery	Fuel Cell			
Secondary Energy Storage		Solar	Beam	Altitude	Flywheel	

Figure 7. Creating model

Creation of a decision model includes performance of paired comparisons based on created map in step 2. During conceptual design, design team should spend more time on decision model. Although, nothing prevents team to ask questions from experts and decision makers for aiding in this process; this questions may be planned through questionnaire or through group meetings. To perform paired comparisons, use two tools: Super Decisions created by ANP group and also, Microsoft Excel and code writing in programming software, performed by researchers. Super Decisions as an object-oriented software provides possibility of creating hierarchical structure for user. Paired comparisons are performed for any level of hierarchical model in Super Decisions software. Figure 8 shows a sample of paired comparisons in Super Decisions software for first level of hierarchical decision model. After determining priority and importance of any component of hierarchical model in a same level using Super Decisions software, collection of priorities and determination of relative weights perform for all hierarchical model components in top-down form (level 4).



2-CLIMB is equally to moderately more important than 1-TAKEOFF

1.	1-TAKEOFF	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	2-CLIMB
2.	1-TAKEOFF	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	3-TRANSIT TO/FROM AREA
3.	1-TAKEOFF	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	4-ORBIT-OVER-SYSTEM
4.	1-TAKEOFF	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	5-TRACK-SYSTEM
5.	1-TAKEOFF	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	6-DROP-EXPENDABLE
6.	1-TAKEOFF	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	7-DESCEND
7.	1-TAKEOFF	>=9.5	9	8	7	6	5	4	3	2		2	3	4	5	6	7	8	9	>=9.5	No comp.	8-LANDING
8.	2-CLIMB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	3-TRANSIT TO/FROM AREA
9.	2-CLIMB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	4-ORBIT-OVER-SYSTEM
10.	2-CLIMB	>=9.5	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	>=9.5	No comp.	5-TRACK-SYSTEM

The inconsistency index is 0.0298. It is desirable to have a value of less than 0.1

1-TAKEOFF	0.314554
2-CLIMB	0.415134
3-TRANSIT TO/FROM AREA	0.854606
4-ORBIT-OVER-SYSTEM	1.000000
5-TRACK-SYSTEM	0.954623
6-DROP-EXPENDABLE	0.658013

Figure 8. Paired Comparisons

This research investigates priorities collection process in different decision making levels as follows: Priorities of first level of hierarchical model (mission segments) are normalized using L1-Norm method. In this way, each component divides on total priorities of the same level until total priorities equal with 1 and there will be no more operation required. For classification step, priorities of each category will be divided on the highest priority. This method is known as Infinite Norm normalization. The component with highest priority equals 1 in performance of this normalization method and this method is named “ideal” in Super Decisions software. Results of multiplying ideal with L1-Norm of a higher level. Normalizing results of step 3 with L1-Norm method in a way that their totals in a same level equal 1. Table 3 Suggested collection Method for second level of hierarchical model.

Table 3. Collecting Results of Paired Comparisons

Mission Segment	Priority	OPS.MoE	Step 1	Step 2	Step 3	Step 4
1-TAKEOFF	0.06719	1-Runway - Dimension	1	1	0.067	0.04
2-CLIMB	0.08863	1-Climb Rate	0.31	0.633	0.056	0.03
		2-Climb Altitude	0.2	0.408	0.036	0.02
		3-Max Bending Strees	0.49	1	0.089	0.05
3-TRANSIT TO/FROM AREA	0.18246	1-Cruise Speed	0.3	0.556	0.101	0.05
		2-Cruise Altitude	0.16	0.296	0.054	0.03
		3-Range	0.54	1	0.182	0.10
4-ORBIT OVER SYSTEM	0.2135	1-Time on Station	0.21	0.350	0.075	0.04
		2-Endurance Altitude	0.13	0.217	0.046	0.02
		3-Endurance Speed	0.07	0.117	0.025	0.01
		4-Latitude Rang	0.6	1	0.214	0.11
		5-Max Rate Sink	0.08	0.133	0.028	0.02
		6-Collect Data	0.29	0.483	0.103	0.05
		7-Store Data	0.16	0.267	0.057	0.03
5-TRACK SYSTEM	0.20381	1-Tracking Speed	0.48	1	0.204	0.11
		2-Tracking Altitude	0.35	0.729	0.149	0.08
		3-Max Turn Rate	0.17	0.354	0.072	0.04
6-DROP EXPANDABLE	0.14049	1-Drop Speed	0.67	1.000	0.140	0.07
		2-Drop Altitude	0.33	0.493	0.069	0.04
7-DESCEND	0.05496	1-Descend Rate	1	1	0.055	0.03
8-LANDING	0.04899	1-Landing Speed	0.67	1	0.049	0.03
		2-Runway - Dimension	0.33	0.493	0.024	0.01

Performing this method and top-down move of hierarchical model gains all relative weights of its model's components in its same level; it also determines rank of any of model components in its level. Table (4-5) shows ranks and relative weights for any level of the model. Paired comparisons result in hierarchical form show effectiveness of collected results of any level of the model on next level.

Evaluation of requirements' importance performs based on criteria for limiting stakeholders. There should be a series of level down criteria as well as level top criteria for limiting number of requirements. Benefit, chance, cost and risk are level top criteria (BOCR), mostly accompanied by ANP/AHP processes. This step tends to determine a level of hierarchical structure, collecting BOCR criteria in it. Benefits, costs and risks of a system mostly are referred to technologies available for systems. Therefore, as shown in figure 8, there is a logic level for collecting these criteria in mapping requirements between Sys.MoE and available technologies of systems. In other words, connection point of decision making model, which its components' importance showed in step 3, applies available technologies, application of benefit, cost and risk criteria.

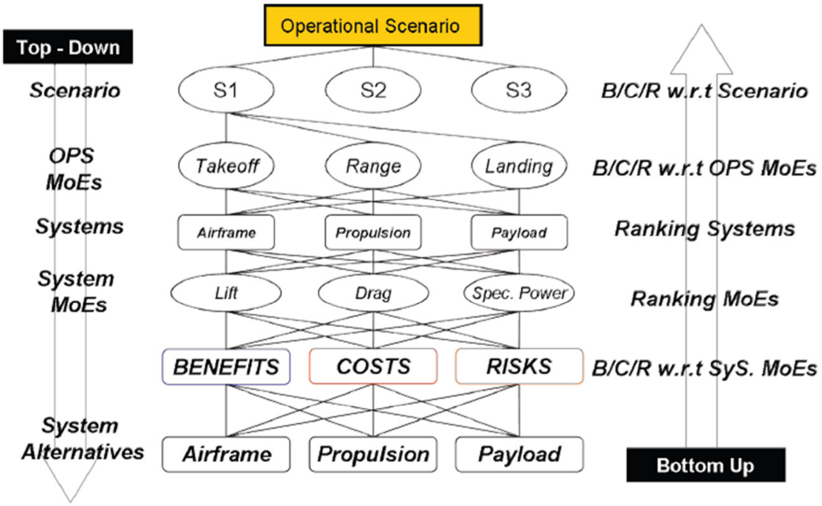


Figure 8. Integration of Benefit, Cost and Risk with Mapping Process

Higher levels of benefits, costs and risks have no clear relations with systems technologies; while, relative importance of elements in higher level should affect systems technologies suggested for gaining missions. At first, the user must identify importance of available technologies. Benefit may be defined as performance in a way that better performances are translated to higher benefits in realization of mission. Costs criteria may apply historical information for cost estimation of any system while, risks criteria may be defined as complexity and safety of any technology.

After performing computations of benefit, cost and risk, any of technologies may be computed based on the following equation and superior combinations may be identified with regard to importance rate of benefit, cost and risk for stakeholders.

$$Additive(negative) = w_b \times B_p - w_c \times C_p - w_r \times R_p \tag{1}$$

In which, (w) indicates weight of criteria; R_p, C_p and B_p indicate benefit, cost and risk for any combination of technologies. The obtained amounts of this equation are named as “Integrated BCR value”. Equation (1) shows efficiency of any combination for lowering risk and cost of the combination; therefore, the combination with a value higher than (0) contains efficiency value higher than total of cost and risk which known as superior (regarding requirements of decision model). In table 4, integrated BCR is computed using equation (1), for a number of combinations compatible with available technologies of figure 9.

This section publishes uncertainty in BCR model. First objective is determination of weight effect in relation with benefit, cost and risk criteria. For instance, if stakeholders have limited budgets, most important requirements will be in relation with cost criteria. Second objective is determination of performance uncertainty effect on BCR model. For a certain number of combinations, this analysis performs for identifying more stable technology than OPS.MoE variations. Table 5 shows considered weights for creation of Monte-Carlo simulations. Note that consistent distribution is used for the three criteria.

Table 4. Computation of Integrated BCR

Engine Type	**Conversion Efficiency**	**Power Source**	**Primary Source**	**Energy Storage**	**Syn. BCR**
Stirling	Variable Pitch Prop	Not Regenerative	Fuel Cell	-	-0.180
Stirling	Variable Pitch Prop	Hybrid	Fuel Cell	Solar	-0.183
Diesel	Variable Pitch Prop	Not Regenerative	Battery	-	0.011
Diesel	Fixed Pitch Prop	Not Regenerative	Fuel Cell	-	-0.119
Electeric Motor	Fixed Pitch Prop	Regenerative	Battery	Flywheel	0.004
IC Engine+Turbo	Variable Pitch Prop	Hybrid	Battery	Altitude	-0.030
Gas Turbine	Jet	Hybrid	Battery	Flywheel	-0.340

Table 5. Benefit, Cost and Risk Distribution Scenario

Criterion Weight	Min Value	Max Value
Benefit	0.3	0.5
Cost	0.3	0.6
Risk	0.2	0.5

Determination of criteria weighting scenario performed in consideration of design team and stakeholders. In above weighing scenario, any criteria may potentially affect the two other scenarios. Target of publication of uncertainty in decision making model for evaluation relates to positivity of integrated BCR value. In other words, which probability contains profit of a combination more than total of its risk and cost, based on this range of weighing criteria?

Integrated BCR value will be computed for any repetition of Monte-Carlo simulation for different combinations of available technologies for investigation and publication of uncertainty in weighing values of profit, cost and risk using codification; positivity of integrated BCR value for any combination was shown in table 6.

Table 6. CDF Values of Selected Combinations

Engine Type	Conversion Efficiency	Power Source	Primary Source	Energy Storage	Probability BCR > 0
IC Engine+Turbo	Variable Pitch Prop	Not Regenerative	Battery	-	**75.60%**
IC Engine+Turbo	Variable Pitch Prop	Regenerative	Battery	Solar	**75.40%**
IC Engine+Turbo	Variable Pitch Prop	Regenerative	Fuel Cell	Solar	**54.80%**
Electeric Motor	Variable Pitch Prop	Not Regenerative	Battery	-	**89.30%**
Electeric Motor	Variable Pitch Prop	Regenerative	Battery	Solar	**89.20%**
Electeric Motor	Variable Pitch Prop	Regenerative	Battery	Altitude	**85.60%**
Electeric Motor	Variable Pitch Prop	Regenerative	Fuel Cell	Solar	**71.60%**
Electeric Motor	Variable Pitch Prop	Hybrid	Battery	Solar	**41.20%**
Diesel	Variable Pitch Prop	Not Regenerative	Battery	-	**72.30%**

Next section of uncertainty refers to identification of uncertainty effect in relative importance of operational features (OPS.MoE) on integrated BCR values for combinations of available technologies. Five combinations of technologies are applied for publication of this uncertainty. In addition, whereas only variations of operational elements are considered, profit, cost and risk weights are as follows:

$$W_b = 0.45, \qquad W_C = 0.35, \qquad W_R = 0.20$$

Applied assumptions in publication of operational uncertainties are similar to table 7. In any repetition of Monte-Carlo simulation, uncertainty from hierarchical model of decision publishes to other levels; therefore, profit, cost and risk values are different for any technology in any repetition (as shown in figure 8). Finally, integrated BCR computes as per mentioned formulas. Computations perform as per codification made in Matlab2009a (code of which shown in appendix). Codification outputs are then exported more easily to Excel environment.

Table 7. Considered Ranges

OPS.MoE	Actual Priority	Minimum	Maximum
1-Runway - Dimension	1	1	1.000
1-Climb Rate	0.311	0.186	0.435
2-Climb Altitude	0.196	0.117	0.274
3-Max Bending Strees	0.493	0.296	0.691
1-Cruise Speed	0.297	0.178	0.416
2-Cruise Altitude	0.163	0.098	0.229
3-Range	0.54	0.324	0.755
1-Time on Station	0.212	0.127	0.297
2-Endurance Altitude	0.131	0.079	0.184
3-Endurance Speed	0.073	0.044	0.102
4-Latitude Rang	0.057	0.034	0.080
5-Max Rate Sink	0.079	0.047	0.110
6-Collect Data	0.289	0.173	0.405
7-Store Data	0.159	0.095	0.222
1-Tracking Speed	0.484	0.29	0.677
2-Tracking Altitude	0.349	0.209	0.488
3-Max Turn Rate	0.168	0.101	0.235
1-Drop Speed	0.667	0.400	0.933
2-Drop Altitude	0.333	0.200	0.467
1-Descend Rate	1	1	1.000
1-Landing Speed	0.667	0.400	0.933
2-Runway - Dimension	0.333	0.200	0.467

Uncertainty published in 10000 Monte-Carlo simulations and general variations of integrated BCR values were listed in table 8.

Table 8. Effects of Operational Uncertainty on BCR Values of Combinations

Engine Type	Initial BCR	Min BCR	Max BCR	BCR Diffrence
IC Engine+Turbo	0.0824	0.79	0.0884	0.7016
IC Engine+Turbo	0.0877	0.0845	0.0933	0.0088
Electeric Motor	0.01067	0.0992	0.1189	0.0197
Electeric Motor	0.1121	0.1046	0.1238	0.0192
Electeric Motor	0.0857	0.0771	0.103	0.0259
Diesel	0.0563	0.0542	0.0594	0.0052

This step is designed to complete requirements methodology upon creation of requirements statement and allocation of resources, required for system design. Based on the results collected from step 5, design team is capable to create a ranking of Sys.MoEs and OPS.MoEs. Regarding collected data of benefit, cost, risk model, the user lists types of resources required for the project (for ex.: monetary, time and technology, etc.). As discussed in Saatym *et al.* (2003), it is possible to apply visible resources data for estimation of invisible resources including general point of view than project, quality and security. Combining both types of data, designing system computes total amount of visible resources required for the project.

5. Conclusion

This section emphasizes on points and superiority of suggested methodologies in relation with defining modeling process and requirement(s). Regarding literature of subject show that QFD process is one of the most general requirements' mapping approaches in academic and industrial scale problems. Figure 9 schematically compares mapping of current requirements (including QFD process) with suggested methodology. Points and superiority of suggested methodology classifies in the following three groups which are explained in next sections: Traceability of elements available in requirements analysis process. Evaluating compatibility of quality comparisons. Structured process for applying available quantitative information or data.

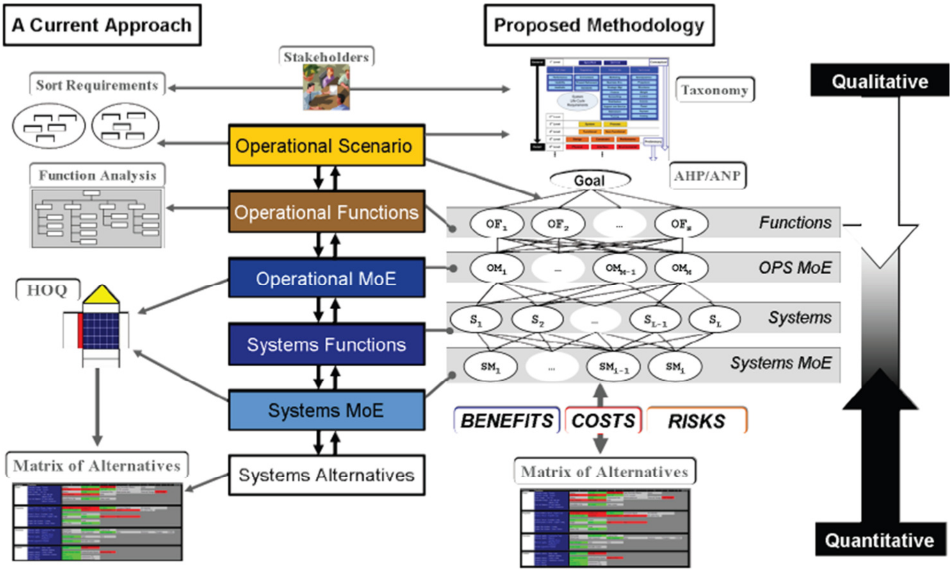


Figure 9: Comparing Current Approach

In suggested methodology, compatibility of quality comparisons may be tested using compatibility coefficient. Compatibility coefficient is a key factor in ANP. This theory provides the chance for evaluation of compatibility coefficient for paired comparisons and main scale. Identifying incompatibility in quality relations requires design team to validate paired comparisons. Performing this, there will be a discussion in team that optimizes cooperation and communication; and it lets team members to assume theories for incompatibility of resources which results in additional information and data about the problem. In addition, suggested methodology applies quantitative information or results taken from designing environment than replacing prepared quantitative comparisons or confirming them. In suggested methodology, a structured process is created to use quantitative data. This capability is possible regarding ratio scale in ANP process. Qualitative and quantitative data me be applied using ration scale or relative scale; therefore, quantitative data (if available) may be applied in any level of requirements mapping. In suggested methodology, requirements mapping performs directly on matrix through benefit, cost and risk model. This capability provides the chance for integrated results feedback. This provides an important t resource for quantitative data which may be applied in confirmation or replacement of qualitative comparisons. Performing this, design team reevaluates relative importance of requirements' mapping components and also, it evaluates effect of quantitative data on selection of system's alternatives. This innovation of suggested methodology brings us a repetitive process between analysis of requirements and systems. Design team could register decision making process with more quantitative data.

First innovation of this research is creation of a suggestive method. This method optimizes requirements comprehensibility upon presenting an organized structure of requirements definition and modeling. The suggested method provides traceability of stakeholders' expectations to alternatives, starting with qualitative data and ending with quantitative data of alternatives. Second innovation of this research is classification of requirements. This classification helps the design team in creation of mental revolution in relation with requirements project; it also may be applied for time information management when using requirements management software including Telelogic Doors. ANP as a frame provides traceability of stakeholders' expectations in alternatives of third main innovation in this research. This frame provides the chance fo analyzing uncertainty using Monte-Carlo simulation method and it selects alternatives using benefit, cost and risk model. Morphologic matrix combination along with ANP and benefit, cost and risk model is an efficient and effective method for comparing alternatives. In relation with ANP framework, another innovation of this research is combined integrated process of different alternative clusters. Only one cluster of alternatives applies in traditional ANP, but considering that a number of alternative clusters and systemic features applied in this research, it required a new approach.

6. Suggestions for Future Researches

Design team provides its required quantitative data based on physical models using simulation and modeling environments instead of using numerical data gained from historical data or past design projects. In future researches, investigate the model for application of resources like time programming, technological investment and the like. This model considers cost in an independent form. It is to be considered that a cost parameter model for lifetime of product integrates with decision model. Alternatives may automatically link to decision model through creating of a computer model based on design environment integrated using new methods of ANP and Monte-Carlo Simulation.

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